REPORT ON SOURCES OF VARIABILITY IN COLOR REPRODUCTION AS VIEWED ON THE HOME TELEVISION RECEIVER

By

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The Ad Hoc Color Television Study Committee was organized in 1968 by the SMPTE under the authorization of the Joint Committee on Intersociety Coordination (JCIC) representing EIA, IEEE, NCTA, SMPTE in order to pinpoint the causes of the serious degradation in color television pictures as viewed in the home, particularly as regards variability in hue, saturation and color quality and to initiate appropriate corrective action by the industry. The continuing investigations have been concerned with every element of the television system from the staging and lighting for electronic and film production, through studio and network transmission, and lastly through the home receiver. Both air and cable transmission have been included in the study. The work has not been limited to paper or theoretical studies, but has involved extensive field tests in several cities in the U.S., laboratory measurements, and detailed surveys of operating practices in over 250 television stations.

The initial examination of the problem areas causing variations, and frequently an accompanying loss of quality, in color pictures indicated that the studies could be classified under three broad categories, viz:

a) Video Signal Parameters and Tolerances

Covering effect on performance of broadcasting equipment and receivers of variations, within the bounds of FCC Rules and Regulations, in parameters such as pulse timing and amplitude, hue and saturation, and color-burst characteristics.

b) Transmission and Transmission Paths

Covering signal processing and transmission from encoding to the home receiver.

c) Picture Origination and Signal Generation

Covering stage, lighting and make-up, electronic camera design and operation, motion-picture production and processing, and all related functions up to the point of signal encoding.

The findings to date emphasize the complexity of the problem - in fact, the causes of color variability. Shortcomings have been found to be so numerous, and to originate from so many elements in the overall system, that in only relatively few instances can any significant improvement be realized by the introduction of fixed corrections at intermediate points. For example, color balance can vary widely from program-to-program, and in fact from scene-to-scene in any single program. Furthermore, differences can be found from station-to-station, and recent data confirms the existence of unacceptable differences among cameras in any one station.

System Field and Laboratory Tests

To attack the first two of these three categories, in December 1968, an extensive combined laboratory and field test was conducted in Chicago to investigate questions of signal parameters and tolerances, variations among transmitters, effects of different signal paths, and the differences in performance of different receiver designs under these various signal conditions. Observations and picture quality grading were made by over 30 observers at Hazeltine Research Laboratories using four different top-of-the-line receivers, all operating with automatic chroma control. The demonstration consisted of 16 closed-circuit tests using Hazeltine facilities, and 6 off-air tests over the local NBC, ABC, CBS stations, all using a common signal source provided by NBC. Slides selected as representative

of a wide gamut of program material were used for the picture source.

A total of 5,139 ratings from the observers was processed. An analysis of the data indicated several important problem areas warranting further investigation and corrective action. These were:

1) FCC signal tolerances permit wide excursions in hue and saturation which can be very objectionable, depending upon receiver design.

2) Transmitters can introduce phase errors which result in objectionable differences among stations. For example, ABC and NBC differed in burst phase by 18-degrees; CBS was midway between.

3) Reports from Zenith, Motorola and Warwick provided phase and saturation errors different from those observed at Hazeltine which could be accounted for only because of differences in propagation and receiving antenna characteristics.

4) Receivers are affected in varying degrees, depending upon circuit design, by differences in burst timing (back porch), duration, amplitude, and energy.

As a result of these findings, action was initiated by the EIA to specify more rigorous signal specifications, taking into account receiver design characteristics, and to develop means to control the significant parameters in the television transmission system.

Furthermore, to explore the transmission variations and resultant problems in greater depth, another more extensive test was conducted in Chicago in April 1969, again using the three network transmitters. This test employed several widely separated receiving sites and included measurements throughout a cable television system in Ottawa, Illinois.

The specific characteristics tested were:

Burst-to-Chroma Phase Shift

Chrominance-Luminance Ratio

Differential Gain and Phase

Chroma-to-Burst Amplitude Ratio

Duration, Amplitude, and Position of Burst

Multipath Effects

Unfortunately, because of difficulties in making measurements under conditions of high noise levels and spurious beat signals encountered in the Ottawa cable television system, this portion of the field test did not yield any meaningful quantitative data. Therefore, another test was conducted by NCTA in July 1969, on a system in Charleston, West Virginia. An analysis of the results of the latter test was more fruitful. Several serious system problems were pinpointed which contributed to the initiation of the development of system performance requirements by the NCTA.

The findings in Chicago test, after computer analysis, confirmed those from the previous field, and provided more conclusive quantitative data for guidance of the EIA BTS Committee in developing improvements in system specifications and test procedures.

Vertical Interval Reference Signals

An extremely important development undertaken by EIA as a result of the Chicago tests has been the development of a Vertical Interval Reference (VIR) Signal. This signal provides a quick go, no-check of luminance and chroma levels, chroma and burst phase, and luminance level corresponding to that of an average skin tone. It also can be used to control automatic luminance and chrominance correction amplifiers which may be located in strategic points in the studio and, master control, and network transmission systems.

The VIR was tested successfully on the ABC, CBS, and NBC networks from August through November 1970. The effectiveness for use in correcting errors in transmitter operation was confirmed in tests over four stations in Portland, Oregon in April 1971. In this test it was found, by means of the VIR, that chroma level on some transmitters was varying as much as 20% with a change in average picture level from 18 to 65%, and thus suitable corrections could be made for this error, as well as other significant errors encountered in burst-to-chroma phase.

Automatic equipment to utilize this signal presently is available, and it appears that sometime this year the FCC will authorize use of this signal.

Processing Amplifier Usage

The Chicago field tests indicated a potential source for signal distortion

in the many processing amplifiers used throughout all television systems, including transmitters. Therefore, a subcommittee was organized to study the problem and to make recommendations for their proper use. Data on 696 processing amplifiers in 284 stations was compiled. In May 1971, a report of the subcommittee's findings and recommendation was released to all NAB member stations.

Subcarrier Distortion and Chrominance/ Luminance Crosstalk

Further under the category of transmission problems, a subcommittee has been assigned to study the significance of distortion and crosstalk of the chrominance and luminance carriers. The study has been directed toward three specific potential areas. These are:

(1) The effect of quadrature distortion.

(2) The effect of transmitter monitoring demodulator characteristics on the VIR signal.

(3) The results of the tests made on microwave transmission systems.

The findings show that techniques and test signals exist which can identify the problems and indicate the correction necessary. A complete report is being prepared and will be released later this year.

Colorimetry

Although the committee activities have continued to cover a broad range of subjects, in the past year particular emphasis has been placed upon the need for standard color measurement and alignment procedures for cameras and monitors. However, the work has been partially stymied by the question of what chromaticity parameters to use for camera taking characteristics. The FCC Rules and Regulations for color broadcasting specify these in terms of picture tube phosphor values. On the other hand, there has been a movement under way to depart from these, taking characteristics in order to accommodate the more restricted gamut of chromaticities provided by present-day phosphors. The principle argument raised in support of such a change has been that present-day phosphors, which provide the high brightness level demanded by the television viewer, cannot be produced with the NTSC/FCC chromaticity values.

The strongest support for a change in camera characteristics has come from the European Broadcasting Union and the Canadian Telecasting Practices Committee. The salient points of the EBU proposal are the following:

1) It may be desirable to modify the agreed-upon characteristics at a later date because of technical progress, i.e. new phosphors.

2) The spectral analysis characteristics of picture-signal sources should be unified on the basis of present phosphors.

3) The signal coding, i.e. the derivation of E'y and the color difference signals should continue to be based upon the FCC reference stimuli.

The EBU recommendations have been referred to the CCIR for consideration as an international standard.

In order to resolve the question, the committee set up a demonstration last year to determine the feasibility of modifying receiver and monitor characteristics by matrixing to compensate for differences in phosphors, rather than that of cameras. The demonstration was arranged for the Committee by RCA at Camden wherein pictures were viewed on two monitors with present-day phosphors, one of which was matrixed to simulate the NTSC/FCC reproducing chromaticities. Since several members of EIA committees concerned with receiver and phosphor characteristics were on hand to view the demonstration and to participate in the ensuing discussion, the meeting represented a total industry involvement.

The picture signals used for the demonstration were generated from a three-channel camera using Plumbicon pick-up tubes. Studio scenes illuminated by 3100K incandescent light were the subject matter. The camera colorimetry characteristics were trimmed with a matrix to reduce color errors to roughly one JND unit. Encoding of the signal was in accordance with FCC specifications.

Both monitors were adjusted to a white balance of D6500 at a reference highlight brightness of 25 foot-lamberts. The transfer characteristic of both monitors was equal to an exponent of 2.2. Hue and saturation were adjusted in the conventional manner for uniform brightness from the red, green, and blue phosphors when driven with a 75% color-bar signal and observed individually. The normal matrix was used in both monitors

during these adjustments.

After adjustment, the special matrix which simulated color reproduction of the NTSC/FCC phosphor characteristics was switched in one monitor. It should be pointed out in this case, that the color errors were not zero because of the impracticability of matrixing linear signals, rather than non-linear signals which are present in the monitor before the characteristic is modified by the picture tube gamma of 2.2. Nevertheless, the errors are reduced substantially, in fact to nearly a 4-to-1 improvement.

The outcome of the demonstration was unanimous agreement among committee members and guests present that the FCC primaries should continue to be followed and that receiver and monitor manufacturers should be responsible for incorporation of the necessary corrections for any differences in phosphor characteristics.

In order to assist the U.S. Delegation, the SMPTE Colorimetry Subcommittee of the Television Committee is preparing a document to be taken under consideration as support for the U.S. position at the Plenary Meeting of the CCIR in 1974. In the meantime, with this matter in hand as far as agreement in the U.S. is concerned, subcommittee work in the development of reference camera and monitor characteristics, as well as related measurement techniques, can proceed.

In regard to practical studio monitor setup procedures using the matrix for simulated NTSC-phosphors, as was noted earlier in this paper, the monitor used in the demonstration in 1972 was set up with the standard NTSC matrix, using standard color bars. The special matrix was switched in for the demonstration. Thus, in order to avoid broadcasters having to acquire special color bar generators which complement the new matrix, it will be necessary to provide a matrix switchable between the conventional characteristics and that which is suitable for present-day phosphors. At least one manufacturer of monitors has announced his intention of monitors has announced his intention of providing such a feature in all new production, as well as a suitable retrofit kit for monitors presently in use. Fortunately, it appears this can be done by merely switching a few fixed resistors -- no active elements are required.

Receiver White Balance

An investigation of receiver color balance was conducted at Eastman Kodak with the cooperation of Motorola to determine if a viewer's tolerance to color variation differs for the usual receiver white balance of 9300K or for the warmer 6500K recommended for studio monitors and referenced in the FCC Rules and Regulations.

For the experiment two good-quality television receivers balanced to 9300K and 6500K respectively were used for display of the picture material. Each receiver was equipped with the optimum matrix for its white balance. In this case, the results showed that significantly more pictures are considered to be good or excellent when displayed on a receiver adjusted to 6500K white balance. A complete report has been published in the April 1973 SMPTE Journal.

Color Film Characteristics

In 1969 extensive measurements were made by Eastman Kodak of density, and skin-tone hue and saturation on several hundred samples of television films - programs, commercials, and news - supplied by the network. This survey was repeated with samples from 1972 programming. The preliminary findings are the following:

1) In general, program films made for television today have less color variations than were found in the earlier study.

2) Films made on the West Coast are balanced noticeably "warmer" than those from the East Coast.

3) Density of program films is closer to recommended values than commercials, the latter having lower or thinner highlight values.

4) Picture quality definitely decreases with decreasing highlight density.

5) There is a continuing tendency to use undesirable production practices in commercials.

6) Most news films are well within recommended ranges of density.

Telecine Camera Characteristics and Operating Characteristics

Presently a broad investigation of telecine characteristics is under way. A subcommittee under Mr. Zwick has gathered data on telecine operation and performance as the first step in an investigation of the need for more precise

alignment specifications, and for standard telecine characteristics. A questionnaire distributed to stations asked the following questions:

1) Brand of equipment used.

2) Operating practices (automatic or non-automatic).

3) Test used for balance, patterns, etc.

4) Use of image enhancement.

5) Type of maintenance.

6) General questions for improvements.

In essence, it has been found that there are serious variability problems associated with telecine equipment and practices. The variation in transfer characteristic has been well documented, and a need for specification of a standard or ideal transfer characteristic is apparent. Variations in color balance and saturation are significant and further work is needed to measure and explain these. In addition, the question of standard operating procedures may need consideration. The contribution of non-standard picture monitors to the telecine variability problem has been pointed out. The influence of the problem of excessive shading on telecine variability is noted.

It may seem paradoxical that the committee has uncovered serious variability problems in telecine operation, and yet the results of the questionnaire show that broadcasters feel they have no real problem with telecine. This comes back to the contention that because the broadcaster tends to attribute all problems with the output of his telecine to the film input only, he fails to recognize any weakness of the telecine operation. The work of the subcommittee will draw attention to these problems inherent in telecine design and operation.

Conclusion

The foregoing has covered the highlights of the investigations over the past several years to reduce the variability in color television reproduction. In brief, it may be stated conclusively that through the diligent efforts of our Ad Hoc Committee and subcommittee members, as well as other committees of the JCIC member organizations, substantial progress is being made toward better, more uniform color pictures for the home viewer.